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Credit and liquidity risk of banks in stress conditions

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Chapter 4

Macro stress-testing methods

4.1 Introduction

By way of introducing part II of the thesis, this chapter provides an overview of stress-testing methods for banks, based on the literature and policy practise, focussing on macro stress-testing. Since the end of the 1990s, stress-testing has been increasingly used by financial institutions and supervisory authorities. It is a tool to quantify the impact of extreme, but plausible shocks in the financial-economic environment on an institution or the financial system as a whole in a forward looking manner. Stress-tests are a welcome addition to risk measures that focus on isolated risks and compute losses by assuming normally distributed risk factors and historic correlations. Stress-tests, on the other hand, focus on tail risks that may relate to a simultaneous realisation of risk factors with historic correlations breaking down (Haldane, 2009).

Stress-testing methods can be identified along two dimensions; micro versus macro and bottom-up versus top-down (Figure 4.1). The main difference between micro and macro stress-testing is that the former is conducted by individual institutions as part of their risk management, while the latter is usually applied by central banks and supervisors to assess the resilience of the financial sector as a whole. There is a range of possible applications between pure micro and classical macro stress-tests. For instance, vertical macro stress-tests - which is a supervisory tool tailored to individual institutions - can be distinguished from horizontal tests, which aim at strengthening the solvency of the banking sector (see Figure 4.1). The second dimension, i.e. bottom-up versus top-down, characterises the level at which a stress-test is conducted, i.c. the financial institutions in a bottom-up test, or the central bank or supervisor in a top-down test. The classification sketched in Figure 4.1 holds for all types of risks that are subject of a stress-test, although the different methods have been mainly applied to credit risk. The methods for liquidity risk are less advanced. Hence, this overview pays most attention to stress-testing of credit risk. After a short introduction of micro stress-testing in Section 4.2, the remainder of the chapter concentrates on macro stress-testing. Section 4.3 describes the bottom-up approach, which Section 4.4 extends with three applications by policymakers in the crisis. Section 4.5 elaborates on top-down approaches, including integrated models for macro stress-testing. Section 4.6 discusses some issues with regard to the use of stress-testing results and Section 4.7 concludes.

4.2 Micro stress-testing

Micro stress-testing has become an increasingly important risk management tool for financial institutions. It can be used to assess portfolio risks, set risk limits and guide the planning of capital resources within an institution. Supervisory frameworks have promoted micro stress-testing. Basel II requires banks to perform stress-tests using their internal models (see column I in Figure 4.1). In this framework, stress-tests for credit risk are prescribed to reflect stress conditions in probabilities of default (PDs) - the main parameter in banks' credit risk models - and to assess the impact of an economic recession on capital requirements ('cyclicality stress-test'). More generally, Basel II requires that banks conduct rigorous, forward-looking stress tests to identify possible events or changes in market conditions that could adversely impact a bank's risk profile and capital adequacy (BCBS, 2006).

Liquidity stress-testing by banks has been less advanced. A survey by the ECB shows that some banks use stress-tests to quantify their liquidity risk tolerance as expressed in survival periods or limit systems (ECB, 2008a). However, the underlying methodologies are highly heterogeneous across the institutions in the sample and based on subjective assumptions. To enhance liquidity stress-testing, in 2008 the Basel Committee has issued principles on which banks should base their internal stress analyses and related quantification of the appropriate liquidity buffer and maturity profile (BCBS, 2008a). Compared to the guidelines for credit risk, the BCBS recommendations for liquidity risk are less explicit on the model parameters that should be stressed. The Committee of European Banking Supervisors (CEBS¹⁹) has also issued guidelines on liquidity stress-testing, which are more precise on the assumptions concerning the impact of stress on the components of the liquidity buffer (CEBS, 2009a).

Banks can conduct stress-tests by using sensitivity analyses or scenario analyses. The former considers the impact of a single shock and is usually performed to assess the stability of model parameters, such as correlations and volatilities. In Basel II it is a way of assessing the robustness of parameters in credit risk models, such as PD or loss given default (LGD). Scenario analysis considers the impact of a combination of two or more assumed shocks on risk portfolios or on the whole institution. To be meaningful for risk management, the scenarios should be tailored to the specific exposures and vulnerabilities of the individual bank.

The recent crisis has revealed several shortcomings of micro stress-tests. They were calibrated on normal market conditions instead of on tail events, scenarios were often too mild and underestimated the liquidity risks of new financial instruments (Senior Supervisors Group, 2008). Furthermore, exposures were usually not stress-tested on the level of the entire organisation, neglecting correlations and risk concentrations across portfolios. To address such failures, the Basel

¹⁹ The CEBS has been succeeded by the European Banking Authority (EBA) in 2011.

Committee has published additional guidelines for micro stress-tests by banks (BCBS, 2009a). One of the purposes of the guidelines is to raise banks' awareness of the link between funding and asset markets in crisis and the related consequences for liquidity and credit risk.

4.3 Bottom-up macro stress-testing

Macro stress-testing is used by central banks and supervisors to quantify the link between macroeconomic variables and the health of either a single financial institution or the financial sector as a whole (ECB, 2006). The practise was spurred by the introduction of macro stress-tests as a part of Financial System Assessment Programs, conducted by the IMF (Jones et al., 2004). In most countries, authorities apply bottom-up stress-tests as a regular health check of the financial sector. In that approach, the central bank or supervisor designs scenarios that the institutions subsequently apply in their internal models. There are several ways to design a scenario in a bottom-up stress-test, for instance with a structural macroeconomic model of the central bank (this method is applied in Chapter 5). Meaningful stress scenarios should represent extreme realisations of underlying risk factors that may strain the financial system. Most bottom-up macro stress-tests focus on credit risk as the main source of risk for banks and use multi-year scenarios to capture downturns in the business cycle, which represent the main risk driver. Market risk is assessed over much shorter time horizons. The difference in the relevant horizons makes a joint treatment of market and credit risk in stress-testing frameworks challenging (Boss et al., 2006). Compared to credit and market risk, stress-testing scenarios usually pay less attention to liquidity risk. It is usually confined to mechanical run-off scenarios, which assume sudden withdrawals of funding (see, for instance, Čihák, 2007). Lastly, scenarios could be more directly tailored to the shock absorption capacity of banks. This could focus on the profitability of banks, taking into account that it is their future capacity to absorb shocks (Coffinet et al., 2009). Or scenarios could be defined by asking the question what shock size would deplete the buffers of a bank. This method of reverse stress-testing translates this impact into a scenario, which is the other way around as commonly applied in stress-tests. A disadvantage is that reverse stress-testing is hard to apply to scenarios with multi-factor shocks, since the correlation between risk factors complicates the translation from the impact into a scenario.

To guide the calculation of stress-test outcomes by the institutions, the central bank or supervisor usually translates the simulated macro shocks in default and loss ratios via reduced form satellite models. These link the macroeconomic variables to the portfolio drivers at the bank level. This macro-micro issue is at the heart of most stress-testing methods (Van Lelyveld, 2009). In bottom-up tests, the macro-micro issue can be dealt with by aligning the stress-test to the individual risk profiles of institutions that participate in the test. Discussions between authorities and institutions on tail risks are a valuable part of the bottom-up approach (Tarullo, 2010). It relates the stress-tests to the

‘real world’ and gives it credibility that is much more difficult to achieve with a top-down approach (see Section 4.5).

As the final step in the process, the stress-test outcomes of the individual banks are aggregated to the level of the system, to judge whether the banking sector as a whole is able to withstand adverse shocks, or whether there are weak spots that could destabilise the sector. The quantification of such contagion risks is usually not part of bottom-up stress-tests. Neither are feedback effects from the banking sector to the real economy commonly part of those exercises. As an approximation, the co-ordinating authority could collect qualitative information on possible management actions and second round effects from the bottom-up stress-test outcomes (DNB, 2007). However, the assessment of possible feed-back effects is complicated by the fact that banks’ behaviour in stress situations is difficult to predict.

4.4 Bottom-up stress-testing in the crisis: three approaches

Traditionally, bottom-up stress-tests aim at assessing the resilience of the financial system to exogenous shocks (column IV in Figure 4.1). In that sense, it is a monitoring device for central banks with a responsibility for financial stability. However, since 2008 bottom-up macro stress-tests have evolved as an instrument to design crisis measures for banks and restore market confidence by increasing the transparency on risk exposures (ECB, 2010b). The use of stress-tests changed the crisis management of authorities from re-active to pro-active, by providing a tool to prepare banks for future shocks. In the crisis, bottom-up stress-tests have been applied either ‘vertically’, as a tool aimed at specific risk exposures or business models (column II in Figure 4.1), or ‘horizontally’, as a sector-wide exercise based on uniform scenarios (column III in Figure 4.1). This classification can be illustrated by the stress-testing approaches applied in the US, UK and the EU during the crisis.

In 2009, the US authorities performed a ‘horizontal’ stress-test to determine banks’ capital requirements under forward-looking scenarios (Board of Governors of the Federal Reserve System, 2009). To ensure similar treatment of the institutions, the macro stress scenarios were translated in default rates on loans that were similar for all banks. Equal capital ratio targets for the participating banks indicated how much additional capital would be needed. Individual bank’s results were published to provide clarity to the markets and thereby make the stress scenario itself less likely to occur. Crucial for the success of this strategy was the US government’s advance announcement that it would replenish possible capital shortfalls in case banks would not be able to raise the required capital in the market.

The Financial Services Authority (FSA) in the UK adopted a different approach, by applying bottom-up stress-tests in a ‘vertical’ way to individual banks on different occasions in 2008 and 2009 (FSA, 2009). The tests were regarded as a regular feature of the supervisory practice instead of a one-

time comprehensive crisis measure, like in the US. Furthermore, the FSA used the stress-tests to determine the amount of capital needed by specific institutions and the extent to which the authorities had to insure certain portfolio risks. Unlike the US supervisory authorities, the FSA adopted tailor made scenarios to individual banks, to reflect the differences in loan quality.

The CEBS coordinated a ‘regional’ macro stress-test to the banking system in the EU, for the first time in 2010 (CEBS, 2009b). Based on common scenarios, the test was applied by local supervisors to a number of large, cross-border European banks in 20 member states. The outcomes provided the authorities with insight into the stability of the banking sector at a regional level. Also, the use of common scenarios and principles has been conducive to the convergence of macro stress-testing methods in the EU. The CEBS did not publish the results of the test by institution, as the exercise was not meant to determine the capital requirements of individual institutions (thereby it was a classical stress-test, see Figure 4.1). In Europe, supervisory measures and recapitalisation of institutions remain the responsibility of the national authorities. The European exercise was the first attempt to capture cross-border risks in a macro stress-test. Cross-border risks are usually neglected in stress-tests, partly because of their complex nature, with liquidity risk as a key factor in transmitting shocks cross-border. Although liquidity risk was not part of the CEBS stress-test, the test shed some light on cross-border risks by applying the scenarios to the banks on a group-wide level, including subsidiaries and branches operating in other countries.

Based on the experiences with macro stress-tests in the crisis, the ECB (2010b) identifies three conditions for the success of bottom-up macro stress-tests: i) clear and synchronised communication of the outcomes, ii) high level of disclosure, iii) complementarities with other policy actions for institutions that do not pass the test. The three approaches applied in the crisis met these conditions to a varying extent, whereby the US approach was deemed to be most successful mitigating the crisis (Véron, 2010).

4.5 Top-down macro stress-testing

In top-down stress-testing methods the central bank or supervisor simulates the impact of adverse shocks to financial institutions or sectors by in-house models (see the lower end of column IV in Figure 4.1). Compared to bottom-up stress-testing, the use of in-house models improves the comparability of outcomes between institutions and provides for a greater flexibility in applying different scenarios, while some models also allow for quantification of the second-round effects in the economy and financial markets. To capture the wide array of financial sector risks, a range of modelling approaches has been developed over the last decade, although they are still mainly confined to the credit risk of banks. According to the various stages of the stress-testing process, we distinguish two strands of models; i) models that establish the link between macro variables and micro risk

drivers, mainly for credit risk and ii) integrated models that include liquidity risk and feedback effects within the financial sector.

4.5.1 Modelling the macro-micro link

Foglia (2009) provides an overview of models that link macro variables to micro risk drivers of bank portfolios. In many cases, macroeconomic models do not include financial sector variables and therefore satellite models are commonly used in stress-testing exercises. These models are usually reduced form satellites for credit risk and map exogenous macro shocks into measures of banks' asset quality. The models differ with regard to the measures of credit quality, level of aggregation and estimation methodology. Two types of (micro) credit risk measures can be distinguished: i) indicators of loan performance, such as non-performing loans and loan loss provisions and ii) default rates of household and/or corporate sectors. The choice of the measures and the level of aggregation in the models mostly depend on data availability, for instance related to the existence of a credit register in a country.

Some studies use loan data of a panel of individual banks, to control for the individual bank characteristics that affect credit risk and banks' different sensitivities to macroeconomic developments (Lehmann and Manz, 2006; see also Chapter 5). Other models estimate credit losses on an industry level, taking into account inter-sector correlations (Düllmann and Erdelmeier, 2009). These correlations are explained by macro variables that represent the systemic risk component and capture contagion effects (Fiori et al., 2009). The studies underline that there could be hidden risks due to unobserved correlation between risks across sectors. Some credit risk models that estimate default rates of corporate borrowers use market-based measures of credit risk, such as Moodys-KMV expected default frequencies (Åsberg and Shahnazarian, 2008), while others use ratings-based measures (Bank of Japan, 2007). Most of the credit risk models use non-linear specifications, such as logit and probit transformations, to take into account that nonlinearities are important when shocks are large (Foglia, 2009).

A sophisticated extension to credit risk models is the portfolio approach, in which sectoral default frequencies are combined with default probabilities of individual borrowers to simulate the overall portfolio credit loss distribution (Boss et al., 2006). A further refinement of the portfolio stress testing method is the incorporation of bank stability measures proposed by Goodhart and Segoviano (2009). They define the banking system as a portfolio of institutions and estimate stability measures, including the distress dependence among the banks in a system.

Credit risk models usually do not take into account feedback effects from credit risk to the macro economy that may relate to shocks to bank's credit exposures that affect lending. Feedback effects do play a role in vector autoregressive (VAR) models that include both macroeconomic variables and measures of default risk in a system of equations, as in Åsberg and Shahnazarian (2008) and Aspachs et al. (2006). The latter study shows that shocks to banks' default probabilities and equity

values can impact economic growth. A similar approach is applied by De Graeve et al. (2008), who integrate a rating model that measures the probability of distress at the bank level into a macroeconomic VAR model. The main disadvantage of the VAR approaches is that they include the feedback effects in a non-structural way and thereby do not explain the complex interactions and transmission channels of financial sector shocks to the real economy.

4.5.2 Integrated models

Models that integrate different satellite models provide a more structural approach to simulate feedback effects within the financial system. These models draw on theoretical work on modelling systemic financial crises. Allen and Gale (2000) explore the spread of contagion in a banking network and Cifuentes et al. (2005) examine how defaults across the network are amplified by asset price effects. The credit crisis has clearly shown the need to assess risks in a systemic perspective, taking into account the possible interlinkages between different risk factors and contagion risks within the financial system. Traditional macro stress-testing methods usually do not include those systemic effects, such as the collapse of the interbank money market and other wholesale markets and the importance of feedback effects between market liquidity and funding liquidity risks of banks.

One of the earliest integrated stress-testing models is the Systemic Risk Monitor (SRM) of the Oesterreichische Nationalbank (Boss et al., 2006), which integrates satellite models of credit and market risk with a network model to evaluate the probability of bank default. In the SRM, shocks to credit and market risk exposures may trigger defaults of banks and this leads to interbank contagion effects in a network model that is build on a matrix of bilateral interbank exposures. A similar integrated framework is the RAMSI model of Bank of England (Alessandri et al., 2009), which consists of a suit of models: a Bayesian VAR model to simulate macroeconomic scenarios, satellite models for credit and market risk and net interest income, an interbank network model and an asset price function to simulate fire sales of assets (market liquidity risk). Both the SRM and RAMSI models do not allow for feedback effects from the banks to the real economy.

The RAMSI model is extended by Aikman et al. (2009) with feedback effects resulting from liquidity risk. Funding liquidity risk on the liability side of banks' balance sheets is included by relating funding costs and market access to a banks' credit rating and confidence effects. In the stress-testing model of Bank of Canada, funding liquidity risk is modelled as an endogenous outcome of the interaction between market liquidity risk, solvency risk and the funding structure of banks (Gauthier et al., 2010). Spill-over effects occur due to the network effects among banks. The interaction between credit and liquidity risk is also modelled by Hui and Wong (2008) in a stress-testing framework, where negative asset price shocks affect banks' liquidity risk through different channels. The shocks raise banks' default risk and induce deposit outflows, they depress the marketability of assets and increase the risk of draw downs on contingent liabilities. In the framework, the linkage between the market and credit risk of banks is established by a Merton-type model, while the liquidity risk of individual banks

is quantified by Monte Carlo simulations. The Liquidity Stress-Tester model described in Chapters 6 and 7 relates to this strand of the literature. It also simulates the liquidity position of banks for different scenarios, taking into account the interaction between market and funding liquidity risks of banks in a macro stress-testing framework.

A pitfall of integrated models for macro stress-testing is that the complexity of the model structure makes the causal linkages and final results less transparent. Thereby the models may violate a basic rule in macro stress-testing, i.e. that models must be kept sufficiently straightforward, transparent and flexible to use and easy to communicate to policymakers and the public (Kwast et al., 2010). On the other hand, integrated models provide a more complete picture of the possible impact of tail events, by taking into account multiple transmission channels and feedback effects.

4.6 Considerations on the use of stress-tests

Micro and macro stress-tests have been increasingly used to determine capital ratios and liquidity buffers of banks. This contributes to a forward looking risk management by institutions and a proactive approach of supervisors. Nonetheless, an important caveat with regard to the use of stress-tests is the considerable uncertainty surrounding the test outcomes. In the first place, the choice of a scenario is basically subjective, while scenarios represent only one possible unfavourable state of the world in an otherwise uncertain future. Breuer et al. (2009) have developed a method to find scenarios that are both plausible and extreme. The uncertainty about the realization of risks is captured by a risk factor distribution that is estimated from historical data. However, this statistical approach neglects possible scenarios that are not in the historic set of data.

Secondly, stress-testing models have even more limitations than models that are used for other purposes, for instance structural macroeconomic models to forecast inflation. Those models generally are local approximations of equilibrium relationships and for this reason they are less suitable for assessing the effects of large shocks (Foglia, 2009). Moreover, data on tail events are scarcely available and in stress situations historic correlations may break down, due to changing behaviour of agents and non-linear adjustment processes. Hence, macro stress-testing models have to cope with large parameter and model uncertainties. In essence this relates to Knightian uncertainty, i.e. there is no distribution of probabilities of extreme events (Knight, 1921). Even if a range of extreme scenarios is simulated, the underlying probability distribution is subjective and thereby possibly a wrong representation of the future.

For these reasons, the outcomes of stress-tests should not be taken as a precise quantification of potential losses, but rather as an indication of the likely impact of tail events. In this vein, they should prepare banks and authorities for possible extreme events. Moreover, the stress-tests could

comfort financial markets if they are accompanied by the publication of underlying exposures, which improves the transparency on the risks that banks face.

4.7 Conclusions

Methods for macro stress-testing are still in a developing stage. Bottom-up stress-testing has recently evolved as a valuable tool for crisis management in the hands of authorities. This has brought macro stress-testing in the realm of prudential supervision. Top-down models have made important advances to improve the macro-micro link by using disaggregated data. Moreover, the development of integrated models enables to simulate feedback effects within the banking sector, although modelling second round effects to the real economy remains an important field for further research.

The outcomes of macro stress-tests are inherently uncertain due to the subjectivity of the scenario choice and model risk. Therefore it is advisable to combine both bottom-up and top-down methods in policymaking. Both approaches complement each other in a valuable way and using them along side each other allows for a cross-check and provides a range of outcomes which helps to quantify the margins of uncertainty.

Figure 4.1. Dimensions of stress-testing

